

Intel Research

Open Source Robotics

Program Overview

February 21, 2003

Intel Research Overview

Intel Research Mission:

"Build the technical leadership, knowledge assets and systems perspective to make Intel a preeminent driver of disruptive information technologies"

- **Intel has 75+ Labs, 4,000 R&D professionals spending \$4B/year**
- **Four Intel-sponsored University Research Facilities**
 - UC-Berkeley, University of Washington, Carnegie Mellon University, Cambridge
- **15 Current Strategic Research Projects**
 - Major categories: Nanotech, Machine Learning, Physics, Ubiquitous Computing
- **Collaborating SRP's focused on Proactive Computing**

Ad-hoc Sensor Networks	Personal Server	Open Source Robotics	Bayesian Networks
Deep Networking	Macroprocessing	Uncertainty	Adaptive Systems

The Next Era of Computing



Converged Devices

Some capabilities that were not possible on a PC will soon be available on millions of personal mobile devices

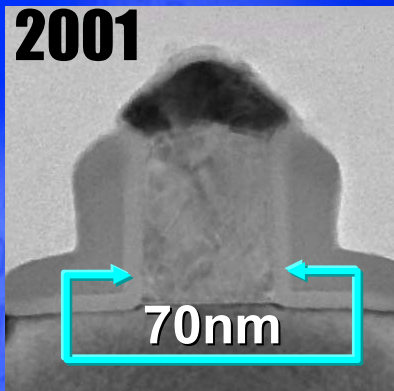
Personal Computers

Bringing desktop computing to millions

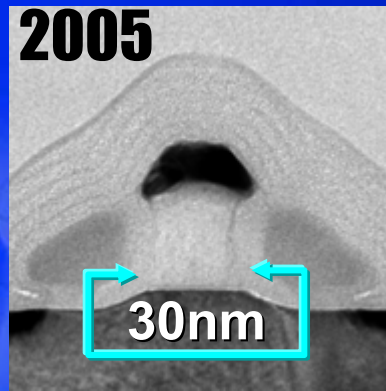
Mainframes



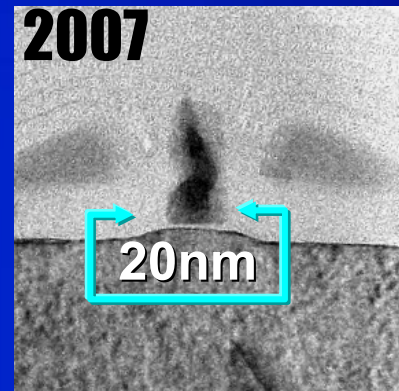
Low Power, High Performance Transistor Design



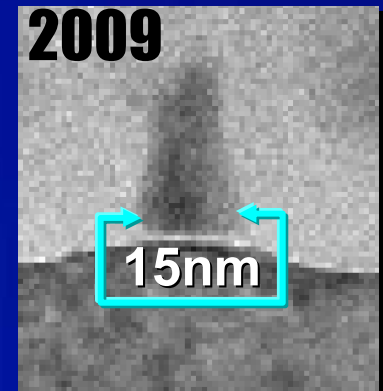
0.13µm process



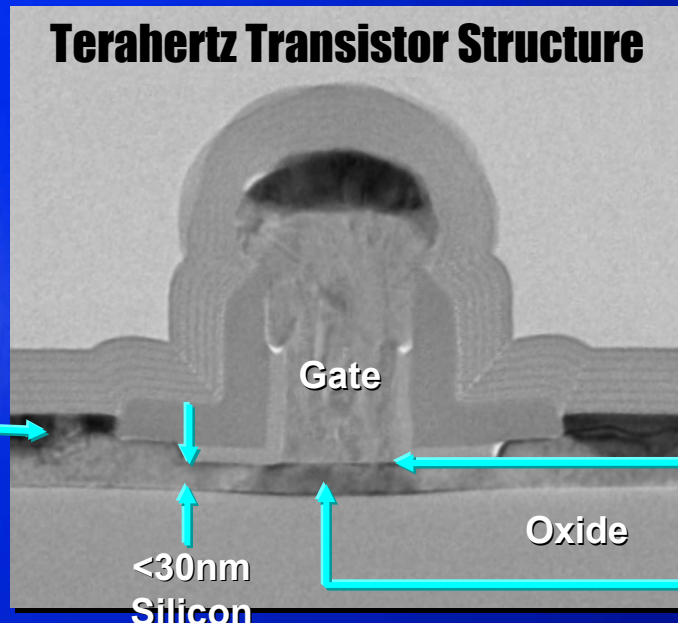
65nm process



45nm process

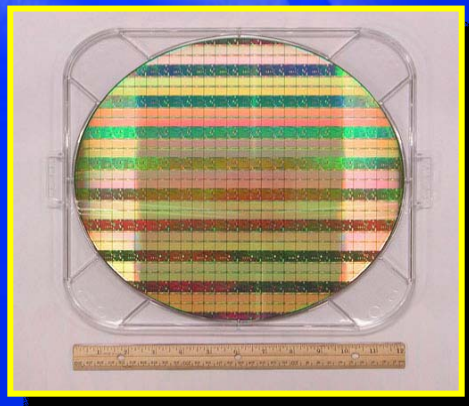


32nm process



New Process Every Two Years

	Actual			Forecast		
Process Name	<u>P858</u>	<u>Px60</u>	<u>P1262</u>	<u>P1264</u>	<u>P1266</u>	<u>P1268</u>
1 st Production	1999	2001	2003	2005	2007	2009
Lithography	0.18 μm	130 nm	90	65	45	32 nm
Gate Length	0.13 μm	65 nm	45	32	22	16 nm



- 90 nm Chip Produced on 300 mm Wafer
- 120 billion transistors!
- Product now shipping

CMOS Radio

Expanding Moore's Law



**Discrete
Components**

**Multiple RF systems
CMOS, MEMS &
Passives Integrated**

**Analog & Digital
integrated on a die**

Intel's Open Source Robotics Program

- **Support Proactive Computing Research using mobile robots and sensor networks**
 - Mobile robots working with and maintaining sensor networks
 - Move computation, communication and caching resources to a location
- **Develop a common computing solution for robotics**
 - Drive open source activities (Linux) and commonly accepted standards (RETF) into the robotics community
 - Work with researchers to develop the most appropriate configurations for the next 5 to 8 years
 - Provide hardware and software building blocks to enable robust robotics applications
- **Build the community of experts**
 - Enable the key researchers who will influence the community
 - Collaborate with the industry participants to provide the robotics systems and infrastructure

University Research Engagements

<u>Professor</u>	<u>University</u>	<u>Update</u>
Illah Nourbakhsh	CMU	Most active participant Demonstrated XScale systems at Forum
Kurt Konolige	Stanford	Samples still in evaluation Needs floating point for stereo vision
Gaurav Sukhatme	USC	All systems and units deployed Sensor net research engaged
Dieter Fox	Washington	Needs floating point systems
Sebastian Thrun	CMU	Deploying XScale systems into UAV's

Tucker Balch	Georgia Tech	Built own XScale board Plans to build a lab with 100's of robots
Doug Hall	PSU	Very active participant Multiple development activities with XScale
Marek Perkowski	PSU	Engaged with Dr. Hall on deploying mobile robot systems

Other University Research Engagements

<u>Professor</u>	<u>University</u>	<u>Update</u>
Vijay Kumar	Penn	Needs Sublimity I/O board DARPA contract for UAV needs XScale weight
Roberto Manduchi	UC-Santa Cruz	DARPA program for robotics sensor fusion Establishing robotics lab at UC-SC
Ken Goldberg	Berkeley	Focused on tele-robotics Currently supported by Research Council
Roland Siegwart	EPFL	Head of EPFL's robotics classes & labs
Lynne Parker	Tennessee	Focused on collaborative robotics
Johann Borenstein	Michigan	Robotics researcher focused on embedded systems for robotics
Dave Auslander	Berkeley	Runs embedded systems lab
Sebastian Thrun	CMU	Needs embedded systems lab to teach classes
Terry Fong	EPFL	Researcher focused on social robotics
Maja Maturic	USC	Director of USC Center for Robotics and Embedded Systems

Robotics Research Continuum

Theoretical / Abstract

Applied/Physical

Machine Learning

Neural Nets
Command
Adaptive

Action Scheduling Priority
USC
Markov Decision Prob
Neural Q Learning

Navigation

Localization
Mapping
Motion Planning
Execution

Geometric Localization
Terrain Occupancy
LVIS Maps
Path Planning
CMU
POMDP's
Stage / Play
Mission: Lab
GA Tech

Sensor Fusion

Vision

Monocular
Stereo
Omnidirectional

Sensing

Visual
Tactile
RF-Based

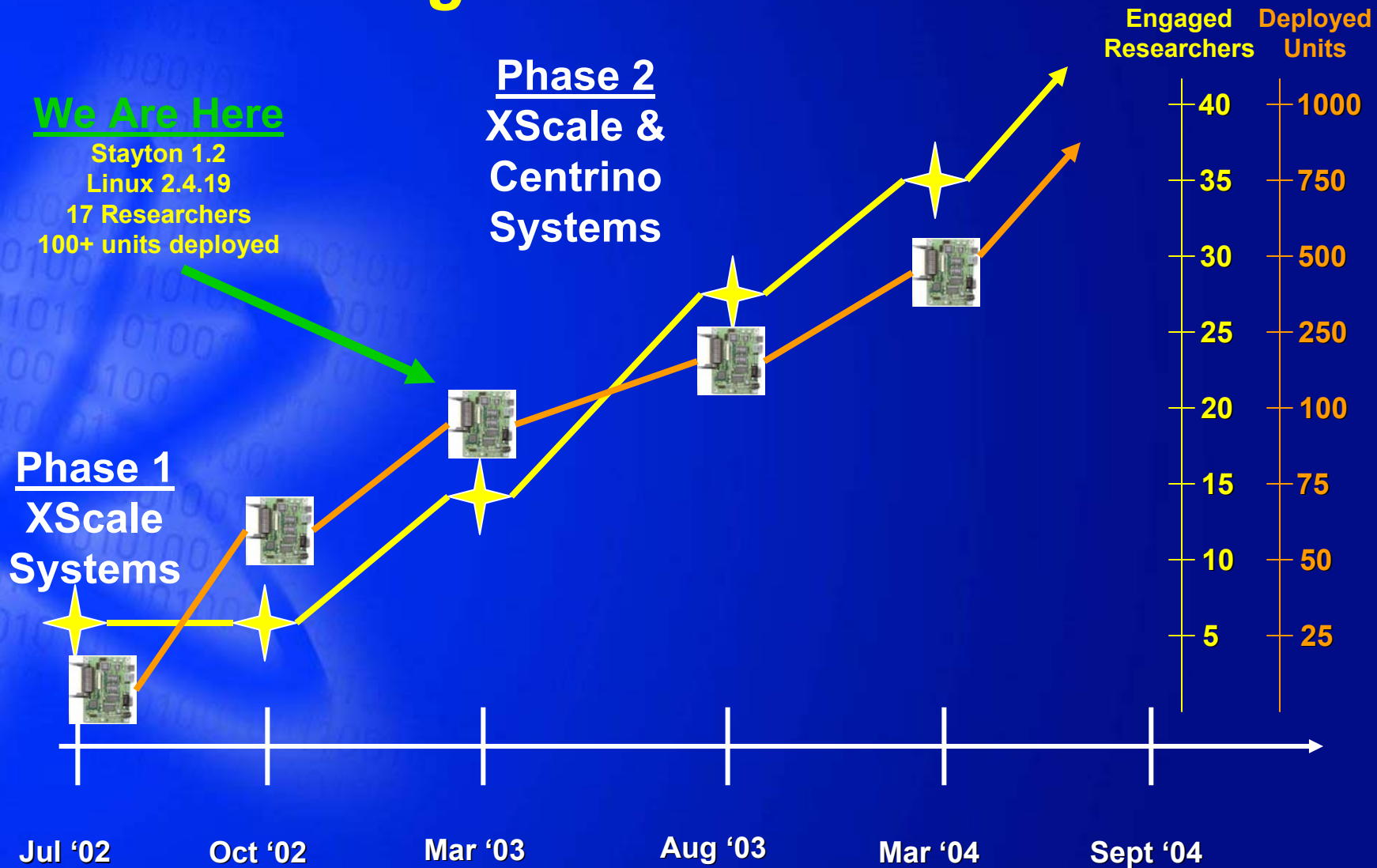
Optical Flow
Feature Extraction
Affinity
Stereo
Telemetry
Bayesian Filters
UW
Stanford
Penn
CMU
Multisensor Integration
Positioning
Global Base Alignment

Locomotion

Wheeled
Tracked
Bipedal
Aerial

Rough Terrain Control
Workpartner
Mixed Reality
Zigzag Control
Active Hybrid
Manitoba

Robotics Program Overview



Intel's Robotics Computing Roadmap

- **2002: Intel® PXA250**
 - Intel® XScale™ technology
 - 400MHz
 - 0.13 micron CMOS
 - Best MIPS/mW
 - Available on “Stayton” boards



- **Next: Intel® PXA262**
 - Lower voltage, lower power
 - Performance enhancements
 - Smaller footprint
 - Intel® StrataFlash™

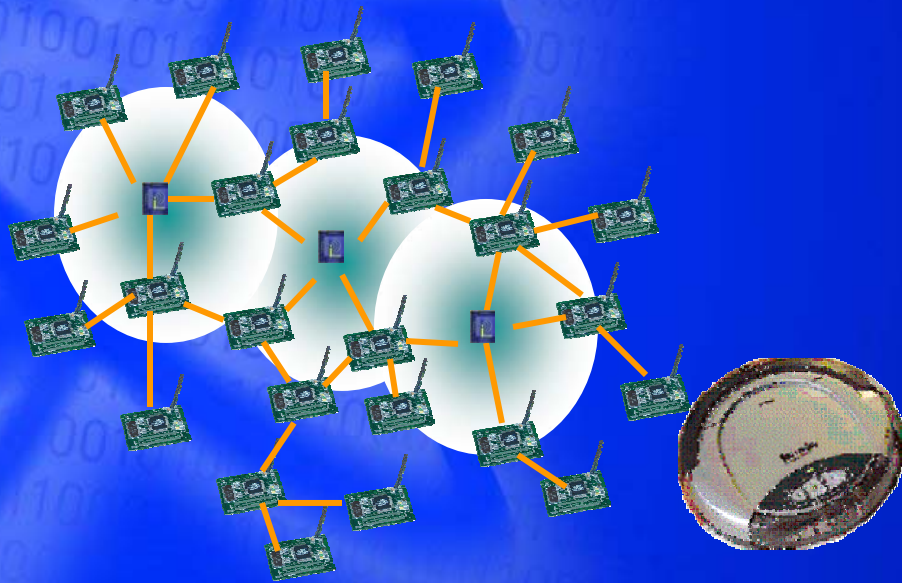
- **Soon: Intel® Centrino™ Mobile Technology**



*Other names and brands may be claimed as the property of others

Next Research Phase

Robots interacting with Motes



- Sensor nets can provide location information to mobile devices
- Ability to offload some sensor fusion algorithms to intelligence in the net
- Utilize information from mote to assist in command and control procedures.

Backup Slides

Intel® PXA262 "System-in-a-package"

Intel StrataFlash®
Memory



9 x 11 mm
(99mm²)

Intel® XScale™
Processor



17 x 17 mm
(289mm²)

=



13 x 13 mm
(169mm²)

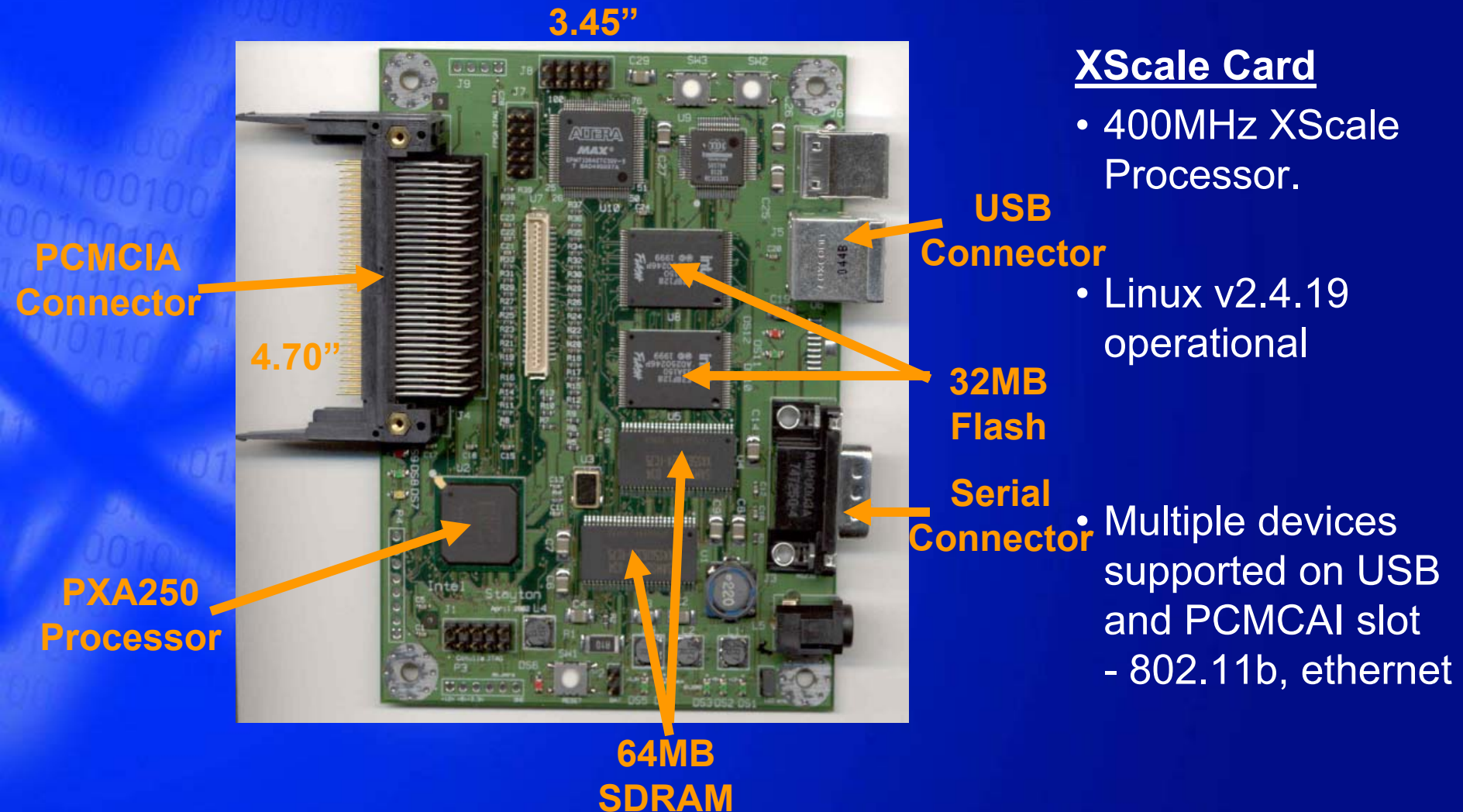
Intel® PXA262
@ 200 & 300MHz
256Mbx16

**Saving 65%+
Space on
Board
Vs 3 discrete!**

Intel's "system-in-a-package" technology is being implemented in new products announced today in the form of the Intel® PXA261 and Intel® PXA262 microprocessors, which are specifically designed for data-enabled wireless handsets based on Intel PCA. The new processors place an Intel® XScale(TM) technology based processor directly on top of Intel StrataFlash memory chips in a single package

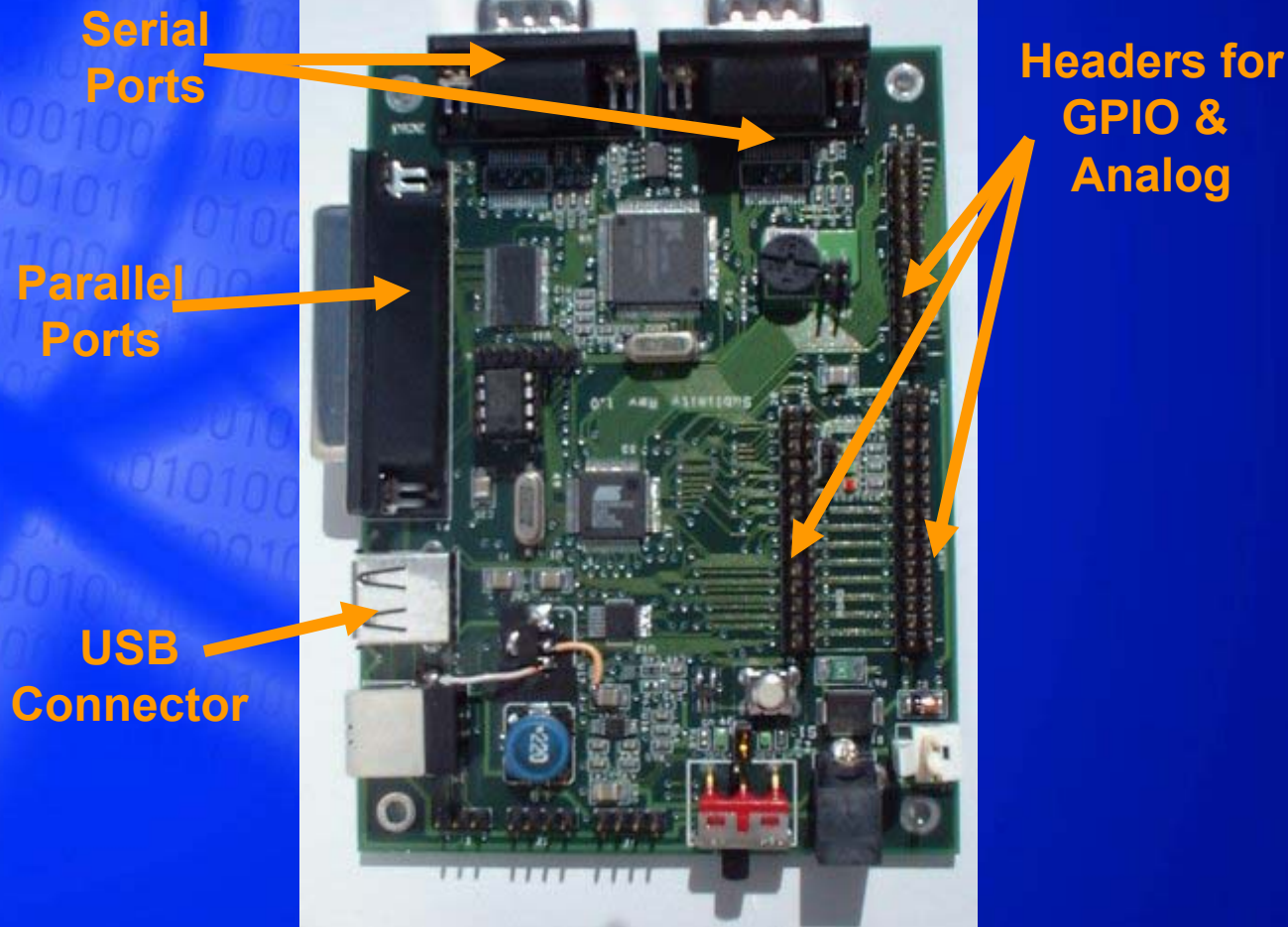
Press Release, IDF Taiwan, October 15th 2002

Stayton – Assembled Board



Sublimity – Robotics Controller Card

Assembled Board



USB Peripheral

- HW Support for legacy ports
- 12 Analog In
- 27 GPIO
- 2 PWM
- 1 I²C